Engineering Notes – Field Use of AyrMesh Hubs

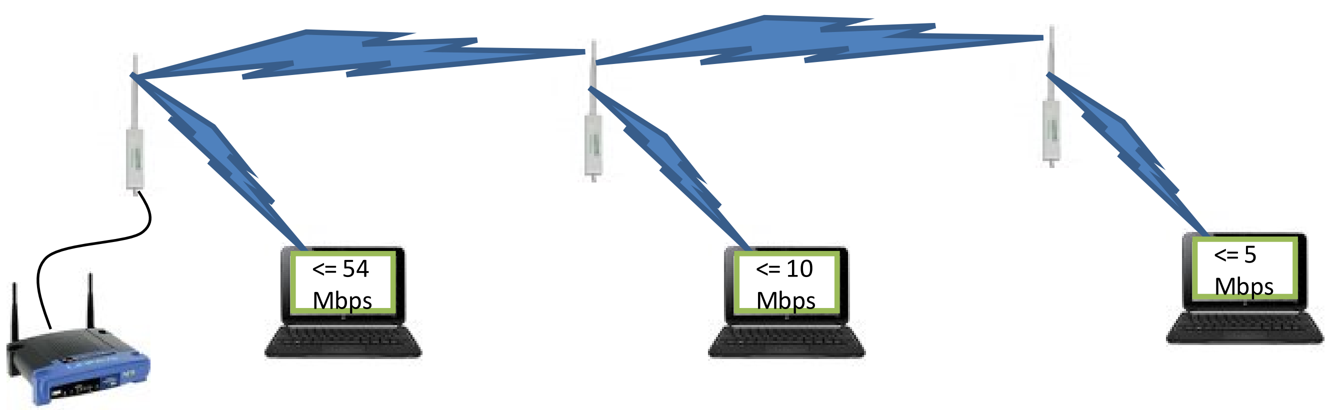
The Ayrstone AyrMesh system has been designed to be used for data collection and internet access in a production agriculture setting. There are several things you should know in building your AyrMesh network for use on your farm, but, with these simple things in mind, you should be able to successfully design and build your farm network.

Glossary

AyrMesh Hub – The basic wireless mesh node in an AyrMesh network.
Gateway Hub – The one AyrMesh Hub connected via Ethernet to the Internet
Remote Hub – an AyrMesh Hub that is not connected via Ethernet to the Internet (connected via wireless to other AyrMesh Hubs)
Mbps – Million bits per second – a speed of 1 Mbps means a 1 MegaByte file can be downloaded in about 8 seconds (8 bits per Byte)

Part 1: Range and bandwidth

In clear line-of-sight, the maximum range between Hubs is 1.5-2 miles (note: this is limited primarily by the networking protocol and less by the radio signal strength from the Hubs). The maximum throughput between Hubs is 11 Million bits per second (Mbps), and is typically 8-10 Mbps. Because AyrMesh is a single-radio meshing system, the bandwidth of the network is halved at each network “hop.” As a result, for instance, a client device using a Gateway Hub might have access to the full speed of the Internet connection, but a device using a Remote Hub being “fed” from that Gateway Hub would have access to, at most 8-10 Mbps. Similarly, a device using a Remote Hub being “fed” from that Remote Hub would have access to, at most 4-5 Mbps.



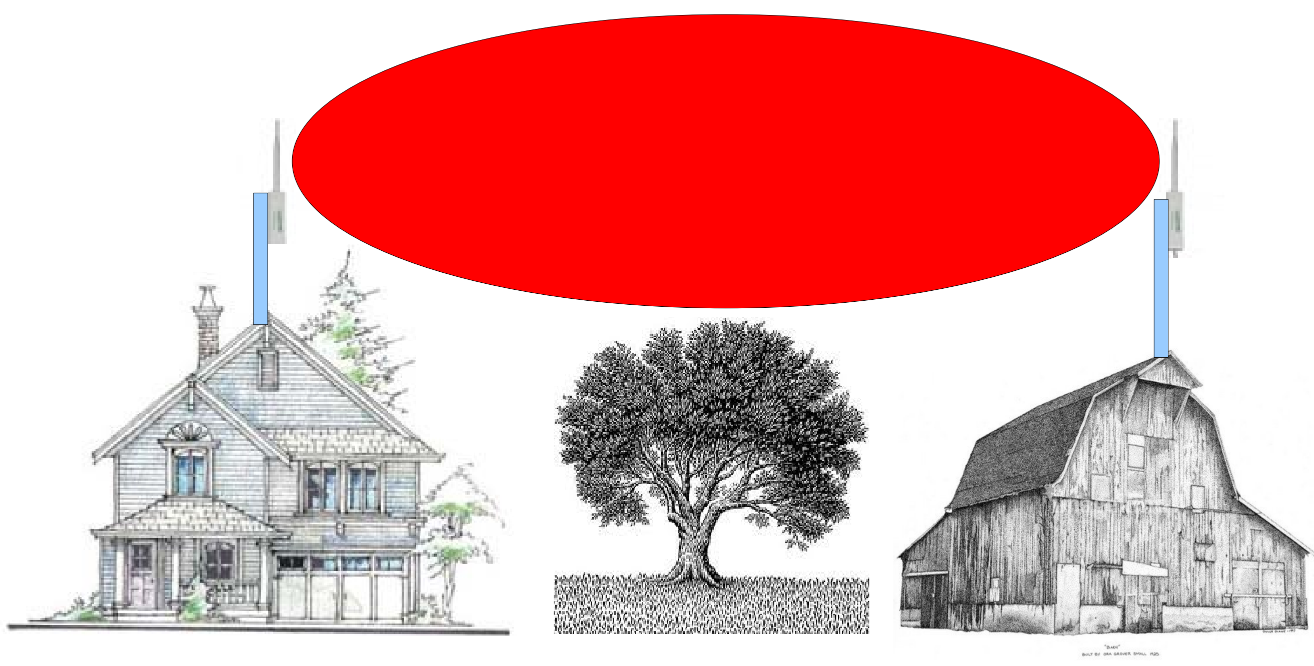
Because of this “halving” of bandwidth at each “hop,” we recommend you use no more than three Remote Hubs from your Gateway if you are using cameras or other relatively high-bandwidth equipment and four Remote Hubs for lower-bandwidth devices (sensors and controls, for instance). This gives you an approximate total “reach” with the AyrMesh system of up to 4.5-6 miles in each direction from the Gateway Hub.

Part 2: Line-of-sight

As the frequency of radio signals increases, they behave more and more like light. In particular, they go in relatively straight lines from transmitter to receiver, and anything that blocks that straight line interferes with the signal.

Note, however, that I say, “relatively” straight lines. The signals actually travel in a football-shaped volume from transmitter to receiver called the “Fresnel Zone.” You can read more about the Fresnel Zone on the internet (Wikipedia has a very good article about it), but it is best described as the volume that would result if you took a football, pumped it up until it was very wide, and then stretched the ends between the two radio stations you're considering.

The trick is to have that Fresnel Zone as clear as possible to ensure good contact between the two radios. Ideally, you keep the Fresnel Zone 80% clear, but 60% is generally considered the minimum. An example is shown below in red:



A key factor is how wide the middle of the Fresnel zone is, and that radius is given by the formula 36.03*sqrt(d/2.437), where d is the distance between the two radios in miles (2.437 is the frequency of WiFi channel 6 in Gigahertz). So, if the two radios are a mile apart, the radius of the Fresnel Zone is 23.1 feet, and you want to have the imaginary line between the two radio antennas at least 23.1 feet above anything standing between them. Note that, at 2 miles, the Fresnel Zone grows to 32.6 feet, while at half a mile it is only 16.3 feet.

This can be a bit tricky, of course: remember, the Fresnel Zone is 3-dimensional; while one usually thinks of things intruding from the bottom of the zone (trees, corn, etc.) note that there can be intrusions from the sides or even the top.

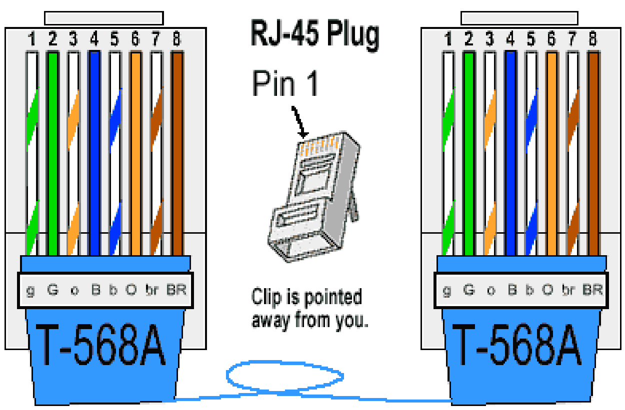
Where this gets very odd is with two hubs that are just “peeking” over an obstacle like a hill. Even though you can get up on a latter and, sitting next to the Hub, see the other Hub “peeking” over the hill, the Hubs may not be able to maintain a solid connection because the Fresnel Zone is about 50% obstructed by the hill. On the other hand, you may have a light tree that is obstructing the line-of-sight, but not enough to prevent the Hubs from having a solid connection because 60% of the signal can “filter” through the leaves. So line-of-sight isn't necessarily line-of-sight.

Part 3: Powering and connecting the Hubs

Of course, if you are putting your Hubs into the field, providing power to them will be an important consideration. Solar or wind power will be needed, along with a battery backup to ensure the Hub remains powered when the sun isn't shining or the wind isn't blowing. You use a Solar Charge Controller to tie all these pieces together:

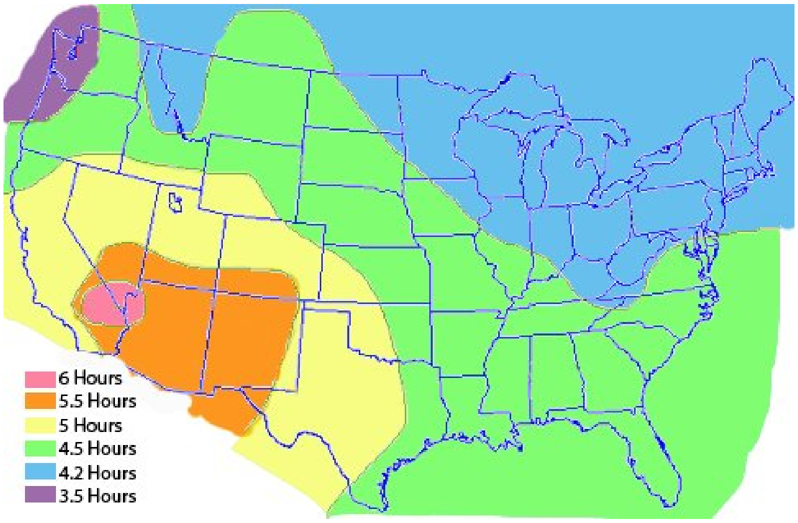
The AyrMesh Hub uses Power over Ethernet so you only have to run one cable to each Hub; to use it in the absence of the PoE injector that plugs into the wall, you must build a cable to take the place of the PoE injector. Online you can find sources for “Passive PoE Injectors, which take care of the wiring of the Ethernet cable, so you just have to apply the DC voltage to the injector:

Alternately, you can modify an Ethernet cable to carry the voltage to the Hub. The current is carried on lines 4, 5, 7, and 8, which are usually the blue/blue & white and brown /brown & white pairs:



The AyrMesh Hub can accept voltages from 9 to 18 Volts DC – the positive voltage is on lines 4 and 5, and the negative (ground) is on lines 7 and 8. If you are handy with electrical connections, this is the easiest way to power the Hub.

One of the most common questions is how to size the solar panel, solar charge controller, and battery. The controller must be sized to your solar panel. The panel and battery should be sized to the load. The Hub itself draws about 4 watts of power most of the time, up to about 8 watts occasionally. To be on the safe side, figure 6 watts. To keep it going 24x7, the Hub will need 6 watts x 24 hours, or 144 watt-hours of electricity per day. You can use an insolation chart or table (find them online) to determine how much sunlight you get on average per day. Here is a sample insolation chart for rough reference:



Divide this into the watt-hours needed to determine the size of solar cell you'll need. For instance, if you live in an area that averages 4 hours per day, you'll need a 144 watt-hour / 4 hours = 36 watt solar cell.

To size the battery, I like to figure that you'll want at least 48 hours without any sunshine. Most modern solar charge controllers have a “shut-off” at 11 volts or so to prevent over-discharge of the battery (preventing damage to the battery and its enclosure). This usually represents about half the total capacity of a deep-cycle battery.

Given that you need 144 watt-hours per day to run the Hub, at 12 volts this 12 amp-hours, or 24 amp-hours for 48 hours. Since you want to use half the capacity of the battery, you'd want at least a 48 amp-hour battery.

Of course, it's not quite this easy: other variables must be included.

First, the efficiency and capacity of lead-acid batteries diminishes very rapidly as the temperature goes down, so you want to oversize the battery (perhaps dramatically) in colder climates. Second, the efficiency of the solar charge controllers varies dramatically – a PWM charge controller may be 70% or less efficient, while an MPPT type charge controller may be as much as 90% efficient. However, you should add these inefficiencies into your equations and increase the size of the solar panel accordingly.

In our example, for instance, you need a 36 watt solar panel, but, given that the solar controller is only 70% efficient, you'd want to use a 51.4-watt solar panel to get the equivalent of 36 watts. If you use a solar controller that's 90% efficient, you'd only need a 40-watt solar panel.

Tycon Power Systems builds and sells fully-integrated small solar power systems, with solar panel, battery, charge controller, and weatherproof case, pole-mountable. We have not evaluated them, but believe them to be of good quality and suitable for use with the AyrMesh Hub.